

sent to the British Museum by Dr. F. Werner, viz. *Chamæleon fischeri*, Reichenow, and *Ch. spinosus*, Matschie. Special interest attached to these species from the fact that they appeared to be more nearly related to the Madagascar species *Ch. bifidus* and *Ch. nasutus* than to any of the numerous forms previously known from Continental Africa.

The following papers were read:—

1. On the Sensory Canal System of Fishes. *Teleostei*—
Suborder A. *Physostomi*. By WALTER EDWARD
COLLINGE, F.Z.S., Assistant Lecturer and Demonstrator
in Zoology and Comparative Anatomy, Mason College,
Birmingham.

[Received March 11, 1895.]

(Plates XVIII.–XXI.)

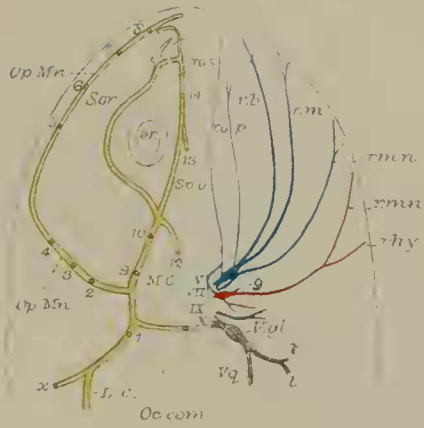
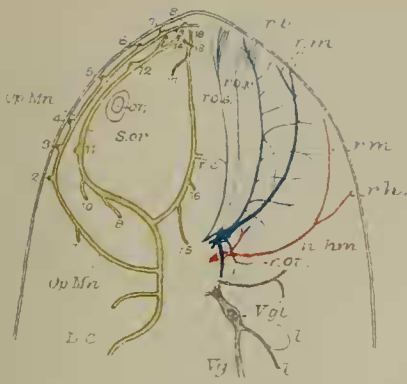
CONTENTS.

	Page		Page
I. INTRODUCTORY	274	IV. ESOCIDÆ	287
II. SILURIDÆ.....	275	<i>Esox lucius</i>	287
1. <i>Clarias nieuhofii</i>	275	General Description ...	287
General Description ...	275	Course of the Canals	
Course of the Canals		and Branches	287
and Branches	276	Innervation	289
Innervation. (<i>Clarias</i>		V. SALMONIDÆ	290
<i>magur</i> .)	277	<i>Salmo salar</i>	290
2. <i>Amiurus catus</i>	278	General Description ...	290
General Description ...	278	Course of the Canals	
Course of the Canals		and Branches	290
and Branches	279	Variation	291
Innervation	280	VI. MURENIDÆ	292
3. <i>Pimelodus maculatus</i> ...	282	<i>Conger conger</i>	292
General Description ...	282	General Description ...	292
Course of the Canals		Course of the Canals	
and Branches	283	and Branches	292
Innervation	284	Innervation	294
4. <i>Callichthys littoralis</i> ...	285	VII. SUMMARY	296
General Description ...	285	VIII. BIBLIOGRAPHY	297
III. CYPRINIDÆ	286	Explanation of the	
<i>Labeo dussumieri</i>	286	Plates	298

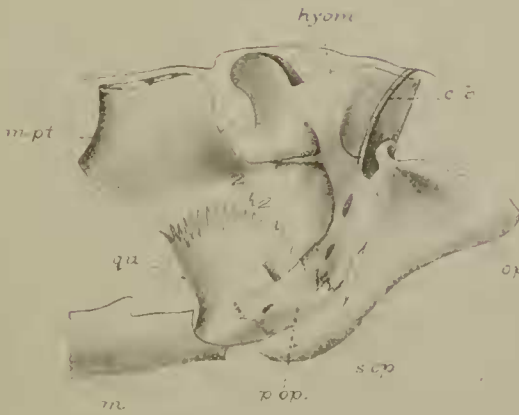
I. INTRODUCTORY.

The system of sensory canals in the Teleostean fishes exhibits so many features of interest both as regards the morphology and histology, and the relations of the cranial nerves to the canals, that it will not be possible to here treat of more than a single sub-order, viz. the Physostomi. The system has been carefully worked out in a number of genera and the most interesting species

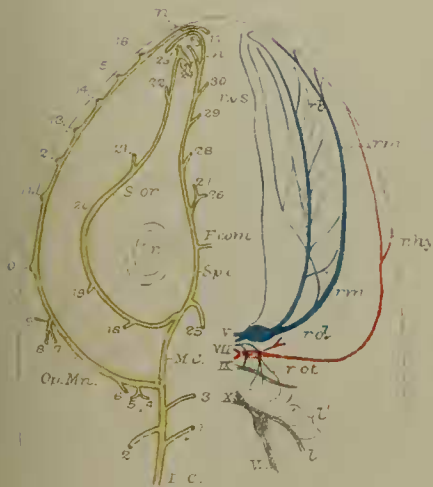
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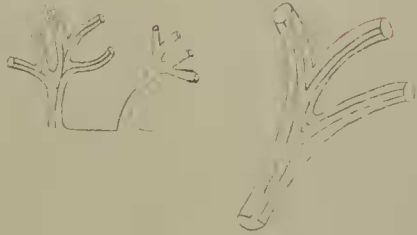
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W. E. C. del. ad nat.
M. F. Parker chromo.

West Newman imp.





V.E. Colad nat F.W.C. fig 7
M.P. Parker chrome

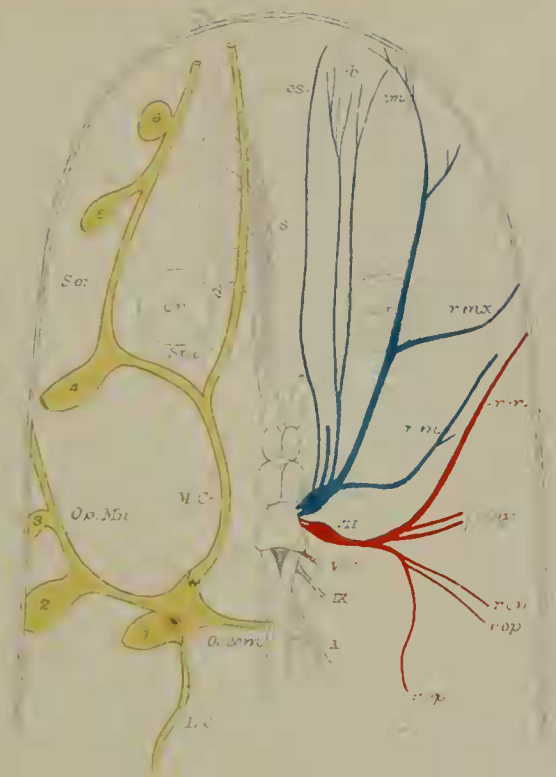
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Sensory Canal System of Fishes

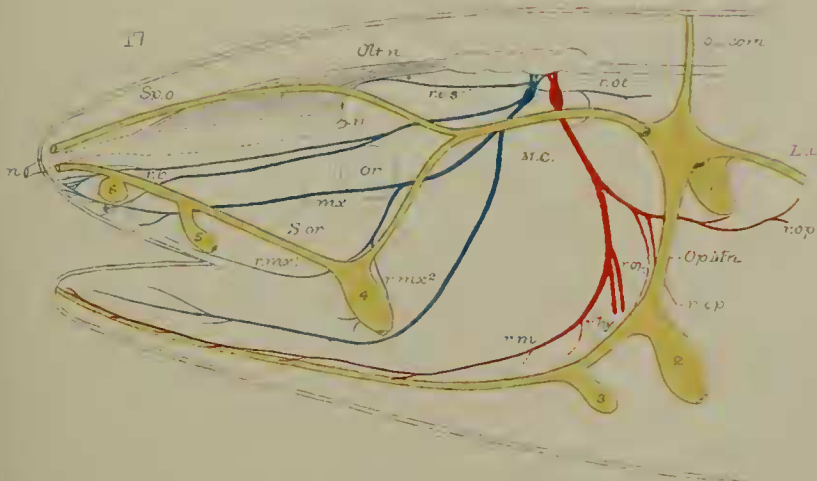




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W.E.C. del ad nat
M.P. Parker chromo.

West, Newman imp.



are described in detail. In all, the system is described in four families, viz. the *Siluridæ*, *Esocidæ*, *Salmonidæ*, and *Murænidæ*, which include eight different species referable to seven genera.

To Professor T. W. Bridge, M.A., of Mason College, Birmingham, I wish to offer my sincere thanks for the specimens of *Clarias*, *Callichthys*, and *Pimelodus*, and for the very generous and continued assistance which he has given me; also to Professor W. C. McIntosh, M.D., F.R.S., for his kindness in granting me the use of a table at the St. Andrews Marine Zoological Laboratory, during the Long Vacation of 1893. My thanks are also due to Dr. Günther, F.R.S., who has identified for me the specimens of *Pimelodus* and *Labeo*.

II. SILURIDÆ.

The sensory canal system of certain genera of this family has been previously described by Ramsay Wright (12) and Pollard (11). The former has given a brief account of the canal system in *Amiurus catus* and a more detailed account of the cranial nerves. Pollard has described and figured the system and its innervation in *Clarias*, *Callichthys paleatus*, *Auchenaspis biscutatus*, *Trichomycterus tenuis*, and *Chaetostomus quairensis*. Except in *Clarias*, he interpreted both the distribution of the sensory canal system and cranial nerves from a series of young specimens cut into sections. Although the cranial nerves of the *Siluridæ* are somewhat difficult to follow, I have preferred dissection as a means of investigation, and it will be noticed on comparing the figures of this author with those here given that there are many points of difference.

The canal system has been worked out in *Clarias nieuhofii*, *Amiurus catus*, *Pimelodus maculatus*, and *Callichthys tittoralis*. The cranial nerves in *Clarias magur*, *Amiurus catus*, and *Pimelodus maculatus*.

1. CLARIAS NIEUHOFII¹.

General Description.

The sensory canal system commences as an exceedingly fine canal slightly in front of the base of the caudal fin. As it passes forwards its diameter increases. There are a series of pores opening into the canal, distributed at somewhat regular intervals. The canal traverses the region of the post-temporal and into the squamosal, from which point it may be regarded as the main canal of the head. It gives off a short backwardly directed branch, and immediately in front of this the operculo-mandibular branch arises (Pl. XVIII. fig. 1, *Op.Mn.*). From the squamosal the main canal continues along the dorsal border of the sphenotic, and divides into supra- and sub-orbital branches (Pl. XVIII. fig. 1): the former passing through the frontal and lateral ethmoid (*Parker*) and giving off in its course three smaller branches and a commissure in

¹ The specimen upon which all measurements, &c., were made was 360 millim. long.

the frontal region; it continues through the nasal and terminates in the premaxilla. The sub-orbital branch passes through the anterior border of the sphenotic and into the post-orbital, in which it gives off a short branch and passes into the sub-orbital, giving off another branch and also opening by a pore. It continues forwards in the pre-orbital, in which in the suture with the nasal there is another pore; it then passes through the nasal bone and terminates in a bifurcation in the maxilla.

Course of the Canals and Branches.

1. THE LATERAL CANAL is an exceedingly fine dermal canal, scarcely visible to the naked eye in the posterior portion of the body. In the anterior region its diameter increases slightly; in no portion, however, was it found in transverse diameter to exceed $\cdot 6$ of a millimetre.

It commences at a small pore 5 millim. in front of the base of the rays of the caudal fin. This terminal portion of the canal is directed somewhat dorsally, and therefore shares in the upward flexure of the terminal part of the vertebral column, as in the tail of *Polyodon*. It continues forwards along the side of the body, rising upon the post-temporal region. Distributed along its whole length are a series of pores, which are largest and most plentiful in the anterior region.

2. THE MAIN CANAL of the head commences in the squamosal. At its commencement it gives off a lateral and backwardly directed branch (Pl. XVIII. fig. 1) which ends blindly, a feature common to very many of the Physostomi. In front of this branch the operculo-mandibular branch arises. The main canal then continues forwards, passing through the dorsal border of the sphenotic. Its course is not perfectly straight, as in many fishes, but has a slight lateral inclination. In the most anterior portion of the sphenotic the canal divides into supra- and sub-orbital branches.

The Supra-orbital Branch.—Leaving the main canal on the anterior border of the sphenotic this branch passes forwards and inwards in the frontal. At its commencement it gives off on its inner side a backwardly directed branch, which passes into the squamosal and terminates at pore 15 (fig. 1). In front of this branch a much smaller one (pore 16) passes off and opens on the dorsal surface of the head. Slightly in front of this, and about the centre of the frontal bone, a branch (fig. 1, *f.com.*) is given off which meets with its fellow of the opposite side, thus forming a frontal commissure and connecting the supra-orbital branches of either side. A similar commissure is present in *Chaetostomus*. From this commissure the canal continues through the frontal and lateral ethmoid, in the latter giving off a lateral and backwardly directed branch terminating at pore 17 (fig. 1), and passes into the nasal, here also branching laterally. The main branch passes forwards into the premaxillæ, on the lateral border of which it terminates at pore 19.

The *Sub-orbital Branch* passes down the anterior border of the sphenotic and through the post-orbital. At the commencement of its course in the post-orbital it gives off the backwardly directed branch terminating at pore 9. Continuing forwards it gives off another similar branch in the sub-orbital bone, which terminates at pore 10. It passes then into the lachrymal, opening by a pore on the suture, and then into the maxilla, where it bifurcates and terminates by the two pores 13 and 14 (fig. 1).

The *Operculo-mandibular Branch* leaves the main canal of the head in the anterior portion of the squamosal, from which it passes into and through the pre- and inter-operculum; in the former it branches, and opens in the latter by pore 2. Leaving the inter-operculum it becomes connected with the mandible by a fine dermal canal. It traverses the whole length of the mandible and in the most anterior portion meets with its fellow of the opposite side. In its course from the main canal of the head to the symphysis of the mandible it opens by eight pores. In *Chaetostomus*, according to Pollard (11. p. 538 and p. 543), the mandibular branch is absent.

3. THE COMMISSURE.—The only commissure present in *Clarias nieuhofii* is that in the frontals, which establishes a connection between the canals of either side of the head. Pollard (11. p. 527) states that this commissure “is distinctly rudimentary and gives very strongly the impression that it formerly united with its fellow of the opposite side.” Again, on p. 542 *op. cit.* he states “it is a complete commissure, but one becoming somewhat rudimentary.” He does not state what species he examined, but in neither of those I have examined are there any signs of it becoming rudimentary. I note further that he omits in his figure (11. pl. 35. fig. 1) any sensory organs in this commissure, one being present in *Clarias magur* on either side of the median lines and innervated by the ramus ophthalmicus superficialis of the trigeminal nerve.

INNERVATION.

Clarias magur.

The nerves innervating the sensory canal system are the trigeminal, facial, glossopharyngeal, and vagus.

Of the trigeminal group the following branches innervate the canals and sensory organs:—

1. The ramus ophthalmicus superficialis.
2. The ramus buccalis.
3. The ramus oticus.

1. The *ramus ophthalmicus superficialis* is the most dorsal branch of the trigeminal and passes directly forwards. It gives off branches to all the sense-organs lying between the pores 16 to 19 on the supra-orbital branch. Slightly posterior to the frontal commissure a short branch passes off which innervates a sense-organ on the lateral border of the commissure. In the anterior

region the nerve divides into two branches, each of these again dividing into numerous fine twigs.

2. *The ramus buccalis* supplies all the sense-organs of the sub-orbital branch. It branches from the Gasserian ganglion above the ramus maxillo-mandibularis, to which it is connected by a fine branch. It passes forwards, crossing the floor of the orbit, and terminates in a series of fine branches. In its course forwards it gives off a series of fine branches which supply the sense-organs between the pores 10 to 15.

3. *The ramus oticus* innervates the greater portion of the main canal and the backwardly directed branch of the supra-orbital branch which terminates at pore number 9 (fig. 1). The ramus oticus passes above the facial (Pl. XVIII. fig. 1, r.ot.) and divides into two branches; the main branch passes backwards along the main canal and the other makes a lateral curve forwards and supplies the small branch which is given off from the supra-orbital branch and terminates at pore 9.

The Facial Nerve.—The only branch entering into connection with the sensory canal system is the ramus mandibularis. This nerve arises as a branch of the ramus hyomandibularis. The latter nerve traverses a canal in the hyomandibular bone, some little distance below which it divides into two; the ramus hyoideus passing ventrally and the ramus mandibularis forwards, giving off numerous branches to the mandibular portion of the operculo-mandibular branch of the sensory canal.

The Glossopharyngeal Nerve in *C. magur* does not run or arise in conjunction with the vagus, as Pollard (11. t. 35. fig. 1) has figured in *Clarias*, sp. In all the specimens examined I find it arises slightly dorsal to, and quite distinct from, the vagus. Its anterior branch passes dorsally, and the posterior one to the posterior portion of the main canal of the head.

The Vagus.—The ramus lateralis vagi passes off from the vagus as a lateral division. It sends off a short branch which passes to the commencement of the main canal; it then proceeds outwards and backwards, giving off a series of fine branches, which pass between the muscles and supply the sense-organs in the anterior region of the lateral canal.

2. AMIURUS CATUS.

General Description.

The sensory canal system of this fish has been briefly described by Ramsay Wright (12) and is also referred to by Allis (1). Very briefly I will give a summary of the observations of these two writers in order that I may not have to point out at any length the differences between our respective accounts.

The references made by Allis are very brief. Speaking of the operculo-mandibular canal in *Amia* he says (p. 473): "The mandibular and opercular portions of the canal develop as two distinct canals, uniting later with each other to form a continuous

line, and then uniting with the main infra-orbital. These later connections in *Amia* are not always found in other fishes . . . in *Amiurus catus* although they unite to form a continuous line, *they do not unite with the main canal*¹."

I shall endeavour to prove that in *Amiurus catus* the operculo-mandibular branch does join with the main canal of the head.

In the account given by Ramsay Wright (12. pp. 262-265) it is stated that the posterior portion of the lateral canal is detached from the remaining portion, which is scarcely correct, and that there is "no communication between the principal canal and that which is lodged in the preoperculum."

Whether or not Professor Ramsay Wright regards the mandibular portion as distinct from the preopercular portion I am unable to gather from his account. On p. 265 he speaks of "the canal which is lodged in the preoperculum and mandible" as if it were continuous; but on the same page he refers to the "independence of the mandibular branch,"—I take this to mean the operculo-mandibular branch.

In *Amiurus catus* there is no true lateral canal. In the posterior portion of the body are a series of short isolated dermal tubes. The interruptions are more frequent and the tubes shorter in the posterior region than in the anterior. Posterior to the operculum there is a coalescence of these short tubes, and a distinct, but very fine, canal is formed. At the point where the lateral canal enters upon the head a short backwardly directed branch is given off (Pl. XVIII. fig. 2, *x*), which passes over the supra-clavicle (*McMurrich*). Immediately after entering the skull an occipital commissure (Pl. XVIII. fig. 2, *Oc.com.*) is given off, which communicates with the main canal of the opposite side; a little further on a lateral branch passes off—the operculo-mandibular branch. The main canal passes forwards, giving off a short branch towards the median line, and posterior to the orbit divides into supra- and sub-orbital branches. The sub-orbital branch passes through a series of canal-bones forming a circumorbital series, from these it is continued forwards into the antorbital bone. The supra-orbital branch runs above the orbit, giving off at its junction with the main canal a short backwardly directed branch, which runs towards the mid-dorsal line; slightly in front of the orbit another similar branch is given off. Passing to the anterior region the supra-orbital branch traverses a small canal-bone (Pl. XVIII. fig. 2) and terminates at the base of the maxillary barblet.

Course of the Canals and Branches.

1. THE LATERAL CANAL consists of a series of isolated dermal tubes; in the posterior portion of the body they are exceedingly small, but become slightly larger in the anterior region. Each tube opens to the surface by one or more pores. Slightly behind the operculum the tubes anastomose with one another and form a fine canal, which gives off a backwardly directed branch

¹ The italics are mine.—W. E. O.

which opens by a pore over the region of the supra-clavicle (*McMurrich*) (Pl. XVIII. fig. 2, *x*).

2. THE MAIN CANAL commences from the point where the above-mentioned branch leaves the lateral canal. It passes through the frontal opening by a pore, immediately in front of which the occipital commissure is given off; some little distance in front of this the main canal receives the operculo-mandibular branch. Its course is now directed forwards and inwards, two pores opening in front of the operculo-mandibular branch. At some little distance posterior to the orbit the canal divides into the supra- and sub-orbital branches.

The Supra-orbital Branch.—At the point of division a backwardly directed branch is given off, which passes towards the mid-dorsal line (Pl. XVIII. fig. 2) opening by pore number 12. The supra-orbital branch continues forwards above the orbit, giving off another branch, which also passes backwards and almost parallel to the main branch; a little distance in front of this a pore opens to the surface, and the canal enters a small canal-bone, through which it passes, giving off a lateral branch which meets with the sub-orbital branch, thus establishing a connection between the two in front of the orbit. After leaving this bone it makes a lateral curve and terminates blindly at the side of the maxillary barblet.

The Sub-orbital Branch is formed by the lower division of the main canal. It passes forwards and outwards for a short distance, and then makes a curve beneath the orbit, passing through the infra-orbital series of canal-bones, and in the anterior region enters a small canal-bone—the antorbital of some authors; passing through this it opens on the inner side and communicates with the supra-orbital branch.

The Operculo-mandibular Branch.—I have already stated that this branch is connected with the main canal; this connection is established by four small drainpipe-like canal-bones which pass from the region of the posterior border of the hyomandibular bone to the lateral border of the frontal (Pl. XVIII. fig. 3, *c.b.*). Passing from the main canal into this series of canal-bones, and through the external portion of the hyomandibular bone, the canal enters the preoperculum; from here it passes into the distal portion of the quadrate and then into the mandible, opening by four pores in its course.

3. THE COMMISSURES.—The only commissure present is the occipital commissure, which connects the main canal of the head of either side with each other. There are two pores opening from it, being situated one on either side of the median line. There is no commissure in the anterior or frontal region.

Innervation.

The cranial nerves of *Amiurus catus* have been described by Ramsay Wright (13), and I have little or nothing to add to his account, excepting their relations to the sensory canal system¹.

¹ The absence of careful figures makes this otherwise excellent account very difficult to follow, the figures on plates i. & iv. being very diagrammatic.

The whole of the sensory canal system of the head is innervated by the trigeminal, facial, and glossopharyngeal; the lateral canal is innervated by the lateralis division of the vagus.

The trigeminal group may be divided into the following main branches, viz. :—

1. The ramus ophthalmicus superficialis.
2. The ramus ophthalmicus profundus.
3. The ramus buccalis.
4. The ramus maxillaris.
5. The ramus mandibularis.
6. The ramus oticus.
7. The ramus lateralis.

Of these seven rami all but the rami ophthalmicus profundus, maxillaris, and lateralis innervate some portion of the sensory canals.

1. *The ramus ophthalmicus superficialis* is with the ramus lateralis, the most dorsal branch of the group. It passes off from the Gasserian ganglion immediately above the ramus ophthalmicus profundus, but not, as mentioned by Ramsay Wright (13. p. 366), through a large foramen. It traverses the dorsal border of the orbit, and then along the upper surface of the skull, supplying a series of cluster-pores in the region of the nasal capsule, and also the sense-organs of the supra-orbital branch.

2. *The ramus ophthalmicus profundus* lies immediately below the ramus ophthalmicus superficialis; after passing through the orbit it branches and enters into connection with the ramus ciliaris.

3. *The ramus buccalis* arises lateral to the ramus ophthalmicus profundus and beneath the ramus ophthalmicus superficialis. It passes forwards and divides into two branches; the lateral branch passes along the borders of the sub-orbital branch of the main sensory canal, to which it gives off a number of fine branches; the inner branch of the buccalis does not innervate any portion of the sensory canal system.

4 & 5. *The ramus maxillo-mandibularis*.—I cannot agree with Professor Ramsay Wright's diagram of these nerves¹ (13. pl. iv. fig. 1). In the final specimen I dissected, which measured 287 millim. in length, I found the ramus maxillaris considerably larger than the ramus mandibularis; the buccalis lies just above it (Pl. XVIII. fig. 2). A few small branches pass off to the integument, the main branch passing to the maxillary region and innervating the maxillary barblet, on which it divides in four branches, passing between the divided tendon of the retractor muscle.

The ramus mandibularis.—In its upper region it is connected with the ramus maxillaris, dividing into external and internal branches on the anterior edge of the mandibular adductor muscle; the former—the ramus externus—passes along the lower jaw, innervating the mandibular portion of the operculo-

¹ Professor Ramsay Wright informs me that part of the work was done on *A. niger*, which may possibly account for some of the differences.

mandibular branch of the main sensory canal, it also communicates with the facial. The ramus internus passes on the inner side of the jaw to the mandibular barblets, &c. I failed to trace any branches of the ramus mandibularis passing to the maxillary barblet (*cf.* Ramsay Wright, 13. p. 368).

6. *The ramus oticus* is larger in *Amiurus catus* than in any of the types previously mentioned. It arises in close conjunction with the ramus ophthalmicus superficialis, passing from the brain through a foramen in the sphenotic. The most dorsal branch innervates the main canal; below this two other branches pass off, while the fourth or main branch passes to the upper portion of the sensory canal in the hyomandibular (Ramsay Wright says pre-operculum). The innervation of this branch of the main canal by the ramus oticus is of special interest, as in most other fishes it is innervated by a branch of the facial nerve. Professor Ramsay Wright (13. p. 366) was the first to describe the distribution of this nerve in *Amiurus*.

The Facial Group.—No portion of the facial nerve, so far as I have been able to trace, innervates any portion of the sensory canal system. As previously pointed out, the descending branch of the ramus oticus replaces the hyomandibular branch of the facial in the upper portion of the operculo-mandibular canal, while the lower portion is innervated by the ramus mandibularis of the trigeminal, the mandibularis of the facial lying below it.

The Glossopharyngeal.—I have not been able to trace any connection between this nerve and the sensory canal system, although it seems very probable that the most posterior portion of the main canal of the head is innervated by it.

The Vagus.—The ramus lateralis vagi leaves the main branch just below the ganglion and passes posteriorly over the supra-clavicle (*McMurrich*); just behind the ascending process of the supra-clavicle it gives off two branches, one passing above to the occipital commissure and the other laterally to the branch *x* (Pl. XVIII. fig. 2, *l* & *l'*).

3. PIMELODUS MACULATUS.

General Description.

The sensory canal system of *Pimelodus* has not hitherto been investigated. Pollard (11) has described and figured that in *Auchenoglanis biscutatus*, a species of an allied genus.

In *Pimelodus* the lateral canal commences at the base of the caudal fin, and passes forwards as a direct line to the region of the head. From its commencement to where the canal passes over the transverse processes of the fourth and fifth vertebræ, which are here developed to an unusual extent (*cf.* Bridge and Haddon, 2. pp. 119–25), there are from 85 to 95 pores, varying in number according to the age of the fish. In the region of the fourth and fifth vertebræ, the canal gives off two branches, one on either side of the canal, and from these a series of smaller branches and

grooves arise, to which special mention will again be made. The canal enters the head just above the angle of the operculum, in which region a dendritic branching is plainly visible and indicates the region of the occipital commissure. Continuing forwards the operculo-mandibular branch passes in a bony canal through the preoperculum and mandible. Slightly in front of this the main canal divides into supra- and sub-orbital branches, the former passing forwards and inwards, and anterior to the nasal capsule, on the lateral border of which it terminates on the side of the nasal barblet. The sub-orbital branch passes around the orbit and forwards, bifurcating between the nares.

Course of the Canals and Branches.

1. THE LATERAL CANAL commences at the base of the fin-rays of the caudal fin, and passes as a fine dermal tube to the region of the head. Opening into the canal at regular intervals are a series of pores averaging from 85 to 95 in number. Previous to entering upon the region of the head a short branch is given off which passes behind the occipital region (Pl. XVIII. fig. 1); a similar branch is given off in front of this, which passes downwards and backwards; both are surrounded by a series of dendritic branches and grooves (Pl. XVIII. fig. 5). These grooves present, I think, a stage in the formation of the branches. In the smallest specimens examined they were simple isolated grooves. In later stages they had sunk into the epidermis, and their sides were gradually converging; still later stages showed that the sides ultimately met and formed a minute canal opening by a terminal pore. In the last stage this minute canal becomes connected with the main canal or one of its branches. In addition to these cluster-pores there are, scattered in the immediate neighbourhood of the lateral canal, a series of small papilla-like organs, to which reference will be made later, it being sufficient to here remark that they are not organs in connection with the sensory canal system.

2. THE MAIN CANAL enters upon the region of the head above the angle of the operculum. On its inner side it gives off the occipital commissure, and slightly anterior to this a lateral branch—the operculo-mandibular: immediately in front of this the main canal divides into the supra- and sub-orbital branches (Pl. XVIII. fig. 4).

The Supra-orbital Branch is formed by the inner division of the main canal. Passing forwards and inwards in the frontals it gives off a short backwardly-directed branch and numerous dendritic branches terminating in cluster-pores. Slightly anterior to the orbit three small branches directed towards the median line are given off, and a short lateral branch between the nasal openings. A number of fine dendritic branches and grooves similar to those already mentioned (Pl. XVIII. fig. 5) are connected with all these. Between the supra-orbital branches of either side of the head are a large number of very small primitive pores.

The Sub-orbital Branch is the lateral division of the main canal. It is conducted around and below the orbit by three small canal-bones. After leaving the most anterior of these the branch is continued as a dermal canal around the lateral border of the nasal capsule and terminates by bifurcating. The dendritic branching is more easily distinguishable here than on the supra-orbital branch; very many of the branches, however, persist as grooves. The whole region of the main canal and its branches—excepting that of the operculo-mandibular branch—is densely covered by exceedingly minute primitive pores. In many cases they were not visible to the naked eye, but could be clearly distinguished with the aid of a low-power lens.

The Operculo-mandibular Branch leaves the main canal a little way in front of the occipital commissure. It passes through the preoperculum and continues along the mandible. At its commencement it gives off numerous fine dermal branches terminating in cluster-pores, the same feature being repeated where it joins with the mandibular portion. There are four large pores on the mandible and numerous small dermal branches and grooves. The branches of the two sides of the head are not connected with each other.

3. THE COMMISSURES.—The two commissures present in *Pimelodus* are an imperfect or rudimentary occipital one, whose presence is easily detected by the series of fine dendritic branches passing from it immediately above the angle of the operculum. The second commissure is that in the frontals (Pl. XVIII. fig. 4, *F.com.*). Like the occipital commissure, it gives off numerous fine dendritic branches. It is not so distinct as the frontal commissure in *Clarias*.

Innervation.

The distribution of the cranial nerves in *Pimelodus* resembles very closely the condition described and figured in *Clarias magur*.

The same four nerves are all that enter into relation with the sensory canal system, viz. the trigeminal, facial, glossopharyngeal, and vagus.

The branches of the trigeminal innervating sense-organs are:—

1. The ramus ophthalmicus superficialis.
2. The ramus buccalis.
3. The ramus oticus.

1. *The ramus ophthalmicus superficialis* has a similar course to this branch in *Clarias*. Fine branches pass off between the pores 25 to 31 to the sense-organs of the supra-orbital branch of the main canal and also to the frontal commissure. In the most anterior portion the nerve divides into two smaller branches, one passing forwards and around the border of the anterior narial opening, the remaining and smaller branch terminating at pore number 31 (Pl. XVIII. fig. 4).

2. *The ramus buccalis* differs slightly from that found in *Clarias* in being longer and in the number of its branches and commissures.

It crosses the ventral portion of the orbit, where a large branch passes off which is connected by a fine commissure with the ramus ophthalmicus profundus, and another with the main branch of the buccalis. The buccalis innervates all the sense-organs lying in the sub-orbital branch of the main sensory canal between the pores 18 to 24. The branches of the nerve lie dorsal to the ramus maxillo-mandibularis.

3. *The ramus oticus* has exactly the same course and distribution as in *Clarias*, innervating the anterior part of the main canal; the centre of the canal is supplied by the glossopharyngeal, and the posterior portion by branches from the lateral division of the vagus (Pl. XVIII. fig. 4).

The Facial, like as in *Clarias*, passes as a main branch through a bony canal in the hyomandibular, and after running ventrally for some short distance, divides into a ramus hyoideus and ramus mandibularis, this latter branch innervating the mandibular portion of the operculo-mandibular branch of the main sensory canal. It would appear that the mandibular rami of the fifth and seventh nerves are interchangeable as regards the innervation of the mandibular portion of the operculo-mandibular branch of the main sensory canal.

Dorsal to the ramus hyomandibularis two small branches arise (Pl. XVIII. fig. 4, *r.d.*), which do not innervate any portion of the sensory canal system and probably correspond to the branches *x* and *y* of Pollard and form the ramus dorsalis.

The Vagus has a similar distribution to that in *Clarias*. It lies immediately behind the glossopharyngeal, but is distinctly independent of it.

4. *CALlichthys littoralis*.

General Description.

The following notes have been made from an external examination of three perfect specimens and the body of a fourth. As I have not been able to inject the canals of the head or to examine the skull in detail, the specimens I examined being required for other purposes, I cannot criticise the account given by Pollard (11. p. 533). It should, however, be borne in mind, when comparing his figure (pl. 36. fig. 4) with that given on Pl. XIX. (fig. 6), that the specimen he investigated was a young one only 3 cm. in length.

1. **THE LATERAL CANAL** commences by a pore at the base of the fin-rays of the caudal fin. It passes forwards as a dermal canal until it reaches the fifth dorsal shield from the head, which it enters and is conducted forwards through the fourth, third, and second, passing into a small canal-bone instead of the first shield.

2. **THE MAIN CANAL** may be regarded as commencing in the aforementioned canal-bone, in which it opens by two pores. Passing into the squamosal it gives off a lateral and backwardly-directed branch running from pore number 4 to 5 (Pl. XIX. fig. 6).

It continues through the squamosal into the sphenotic and in the region of pore number 7 divides into two branches, viz. the supra- and sub-orbital.

The Supra-orbital Branch passes through the sphenotic into the frontal and makes a sharp turn to the region of pore number 9 (Pl. XIX. fig. 6), and then in an outward curve passes around the anterior nasal opening, where it terminates.

The Sub-orbital Branch passes posterior and ventral to the orbit in the sub-orbital bones, opening in its course by three pores.

In the specimens I examined, the operculo-mandibular branch differed from that figured and described by Pollard (11. p. 534) in that there is a distinct mandibular portion. It is not connected with the main canal of the head, but arises near the head of the preoperculum, through which it passes; opening by three pores it passes into the mandible, in which portion there is a single pore, number 4 (Pl. XIX. fig. 6).

The species examined by Pollard was *C. paleatus*. If the condition figured by this author is correct for the adult stages of *C. paleatus* and *Trichomyterus tenuis*—he examined only young forms of both—they are very interesting, and offer perhaps the simplest type of sensory canals in the Physostomi.

III. CYPRINIDÆ.

LABEO DUSSUMIERI.

I do not propose to describe the sensory canal system in *Labeo*, but wish to draw attention to the presence in this family of a series of sense-organs which, so far as I can learn, are peculiar to it.

Valenciennes¹ was the first, I believe, to make any mention of them, and later Bleeker² pointed out their presence. Neither of these authors described their structure, which was first detailed and figured by Leydig (8) in the thorough and careful manner characteristic of all this author's work³. It is rather singular, but I cannot find a single reference to this very important paper in any of the writings of recent workers upon the subject.

In *Labeo* there are distributed over the anterior region of the head and around the borders of the mouth a large series of pores of different sizes with overlapping edges standing above the level of the skin. These edges are quite smooth and unpigmented (Pl. XIX. fig. 7).

Each pore leads into a flask-shaped cavity varying in size according to the size of the pore (Pl. XIX. fig. 8). The latter average from 1 to 3 millim. in diameter in *Labeo dussumieri*, the cavity being from 3 to 10 millim. in depth. From the

¹ Cuvier et Valenciennes, Hist. Nat. des Poissons, 1842, vol. xvi.

² Bleeker, Atlas ichthyol. d. Indes-Orientales Néerlandaises, 1863, t. iii.

³ The species described by Leydig are *Schismatorhynchus heterorhynchus*, Blkr., *Lobocheilus falcifer*, van Hass., and *Rohita vittata*, Val. Bleeker makes mention of their presence in various species of the following genera:—*Crossocheilus*, *Labeo*, *Lobocheilus*, *Schismatorhynchus*, *Epalzcorynchus*, *Rohita*, *Diplocheilichthys*, *Morulus*, and *Danzila*.

sides of the walls of each cavity there arise a series of sensory filaments (Pl. XIX. figs. 8 and 9) into which a fine branch of a nerve passes. In *Schismatorhynchus heterorhynchus*, Leydig (8. p. 2) describes the walls as showing folds as figured (Taf. i. fig. 5). In *Labeo* these folds were scarcely discernible, probably owing to the fact that the material had been for some time in alcohol.

These interesting organs seem to me to be a series of specialized cluster-pores which have become isolated from the sensory canal system. There are a number of other "sense-papillæ," as Leydig terms them, common to certain *Cyprinidæ*, which have also probably originated as cluster-pores.

IV. ESOCIDÆ.

ESOX LUCIUS.

General Description.

The sensory canal system of *Esox* has been previously investigated or referred to by Leydig (7), M'Donnell (9), Ramsay Wright (12), Allis (1), and others.

The system is a simple one and shows none of the complications previously met with in the Siluroids or Cyprinoids.

The lateral canal, like all the canals in *Esox*, is a wide tube passing from the posterior end of the body to the anterior, and joins the main canal of the head by passing through the supra-clavicle and a somewhat Y-shaped canal-bone; the lateral arm connects the lateral canal of the trunk with the main canal of the head, which passes through the lateral border of the pterotic, and on the sphenotic divides into supra- and suborbital branches. The former passes through the frontal to a point slightly anterior to the lateral ethmoid, and then into a canal-bone lying on the lateral border of the anterior portion of the frontal. It terminates anterior to the nasal capsule some distance from the end of the snout. The suborbital passes over the sphenotic in a small ovoid canal-bone and is conducted around the orbit in a series of canal-bones. In front of the orbit it makes an upward turn and terminates at a pore lateral to the nasal capsule.

Passing through the preoperculum is a fairly large canal, which has no connection with the main canal or with that in the mandible. This last mentioned commences on the ventral surface of the mandible a little anterior to the articular portion, and passes to almost the end of the ramus. It is not connected with the branch of the opposite side.

In addition to the above canals and branches there are in *Esox* a number of open grooves upon the surface of the head posterior to the occipital region and in the nasal region.

Course of the Canals and Branches.

1. THE LATERAL CANAL.—The presence of a canal on the lateral trunk of the body seems to have escaped the notice of previous

observers; thus M'Donnell (9. p. 175) describes the lateral canal as consisting of a series of isolated follicles each opening to the surface by a pore. Even so careful an observer as Leydig (7. p. 33) speaks of it as an interrupted canal, possibly being misled by the series of interrupted scales. Ramsay Wright (12. p. 265) also refers to it in like terms.

Notwithstanding these observations, there is a distinct and very large lateral canal in *Esox*. It commences about 12 millim. from the base of the caudal fin and passes as a wide tube as far as the supraclavicle. Its greatest transverse diameter is 5 millim. and its smallest 1 millim. It opens to the surface by a series of pores, each lying in a little pit. The canal lies beneath the scales in the dermis. The sensory organs lie slightly anterior to the pore.

In transverse section the canal exhibited the usual structure.

2. THE MAIN CANAL of the Head.—This canal enters the skull in the pterotic, through which it passes as a wide canal. M'Donnell (9. p. 175) states that the cephalic portion and the lateral line proper are not connected with each other. Probably he overlooked the portion traversing the supraclavicle and the Y-shaped canal-bone. The main canal terminates at the anterior end of the pterotic, giving rise to the supra- and sub-orbital branches.

The Supra-orbital Branch lies in the frontal bone. It is a simple wide canal opening to the surface by four large pore-like openings. From the frontal it passes into a canal-bone lying on the lateral border of the frontal, and terminates some little distance in front of the nasal capsule.

The Sub-orbital Branch first passes through a small oval-shaped ossicle lying upon the sphenotic, and continues its course through a series of canal-bones surrounding the orbit, in front of which it makes an upward turn and terminates by opening to the surface external to the nasal capsule.

The Opercular Branch.—Unlike the condition found in most fishes, the opercular branch is quite distinct from either the main canal of the head or the mandibular branch. Commencing at the head of the preoperculum as a large pore, it passes through this bone to its distal end, where it terminates by a similar pore. In its course through the bone it gives off three small branches, each of which opens to the surface by a pore.

The Mandibular Branch passes through the greater portion of the mandible as a closed canal opening to the surface by three pores, as well as one at its commencement and termination. It terminates about 13 millim. from the symphysis.

In *Esox* there are no true commissures connecting the canals of one side of the head with the other, but a series of open grooves upon certain regions of the head probably take their place. Behind the occipital region these are most pronounced. They commence on either side of the head from the pore on the inner arm of the Y-shaped canal-bone previously mentioned. Some portions of these grooves anastomose with each other in the median line, thus forming a connection between the canals of each

side of the head. A similar series of grooves are present in the nasal region, these entering into connection with the terminal pore of the supra-orbital branch of the main canal. There is no anastomosis of the grooves of one side with the other.

Innervation.

In describing the cranial nerves of the Selachoid Ganoids (3) attention was drawn to the great development of the facial nerve. So far in the Physostomous Teleosts the trigeminal has been the larger, and this is perhaps more evident in *Esox lucius* than in any type previously described.

The sensory canal system is innervated by the same four groups, viz. the trigeminal, facial, glossopharyngeal, and vagus.

The Trigeminal Group.—The branches supplying the sensory canal system are:—

1. The ramus ophthalmicus superficialis.
2. The ramus buccalis.
3. The ramus oticus.
4. The ramus mandibularis.

1. *The ramus ophthalmicus superficialis* is the most dorsal branch of the trigeminal group (Pl. XX. fig. 11). It passes forwards some distance above the orbit and divides into two smaller branches, which each terminate in a number of fine divisions some little distance from the snout. The nerve lies beneath the supra-orbital branch of the sensory canal, to which it gives off a series of fine twigs.

2. *The ramus buccalis.*—The main divisions of the trigeminal are the ramus buccalis and the ramus maxillo-mandibularis; the former is the anterior and more dorsal division and passes behind and beneath the orbit, and then across the side of the face, where it divides into two, each division further dividing into a number of fine twigs which spread themselves over the terminal region of the snout. From the main branch of the buccalis a fine branch passes off to the sub-orbital branch of the main sensory canal, giving off a series of fine twigs to the sensory organs (Pl. XX. figs. 10, 11).

3. *The ramus oticus* arises in close proximity to the ramus ophthalmicus superficialis. It passes posteriorly and divides into two, the dorsal branch innervating the main canal of the head (fig. 10, *r.ot.*).

4. *The ramus maxillo-mandibularis* is the largest division of the trigeminal group. It passes ventrally to the angle of the jaw, where it divides into internal and external mandibular branches. Some little distance above the internus the ramus maxillaris passes off (Pl. XX. figs. 10, 11). The ramus mandibularis externus innervates the mandibular canal; it passes on the ventral portion of the mandible and gives off two series of fine branches, one to the canal and the other to the integument. The ramus internus divides on the inner side of the mandible into numerous smaller branches (Pl. XX. fig. 12).

The Facial Group.—The only branch of the facial which I have been able to satisfy myself actually innervates a portion of the sensory canal system is the most posterior division of this group—the ramus hyoideus—which runs in the ventral portion of the preoperculum and innervates the canal which traverses that bone. The ramus mandibularis (Pl. XX. figs. 10, 11, *r.m.*) lies below the mandibular branch of the trigeminal and does not enter into relation with the branch of the canal. A small branch (Pl. XX. figs. 10, 11, *v*) in some cases was in very close relationship with the sub-orbital branch of the main canal, but no fibres could be traced to the sensory organs. There would seem to be no innervation to the upper portion of the canal in the preoperculum, neither the ramus oticus nor the glossopharyngeal entering that region.

The Vagus passes directly backwards, giving off a lateral branch and other smaller branches. The lateralis vagi lies dorsally as far back as the supracleivle, passing beneath that bone, at a point about at its upper third; it then makes a downward curve to the region of the lateral canal, which it innervates.

V. SALMONIDÆ.

SALMO SALAR.

General Description.

The lateral canal commences at the base of the caudal fin and passes anteriorly as a dermal canal. In its course forwards it opens to the surface by a series of pores which pass between the scales, those scales in the region of the lateral canal being slightly modified.

It enters upon the head in the region of the pterotic bone, giving off an occipital commissure and, anterior to this, the operculo-mandibular branch. Posterior to the orbit it divides into supra- and sub-orbital branches, the former passing some little distance above the orbit and the latter through a series of canal-bones forming the circumorbital ring.

A number of variations in the branching and distribution of the main canal of the head and its branches were noted in the various specimens dissected. I shall first describe what I consider to be the typical form, and then make mention of some of the variations met with.

Course of the Canals and Branches.

1. The LATERAL CANAL is a dermal one like that in *Esox*; it commences at the base of the caudal fin, and in its course forwards opens to the surface by a series of pores which, as described above, pass between the scales, there being a slight modification in those scales in the region of the lateral canal.

2. The MAIN CANAL of the head is a fine canal enclosed within a series of small drainpipe-like canal-bones (Pl. XX. fig. 15), not unlike those figured and described in *Polyodon* (3. pl. 39. fig. 7, *e*). It enters upon the region of the head above the pterotic and gives off an occipital commissure in the occipital

region, and some little distance in front of this a lateral branch passes off—the operculo-mandibular branch. The canal then makes a slight ventral curve, and posterior to the orbit divides into supra- and sub-orbital branches.

The Supra-orbital Branch, like the main canal, is conducted in its course by a series of small drainpipe-like canal-bones. It passes forwards and inwards to a point directly above the orbit, and then makes a curve towards the nasal capsule, dorsal and anterior to which it terminates by a minute pore.

The Sub-orbital Branch passes from the main canal on the lateral border of the frontal in a series of canal-bones forming the circum-orbital series. These conduct the branch around the inferior and posterior borders of the orbit, the branch terminating ventral and slightly posterior to the nasal capsule.

The Operculo-mandibular Branch.—Leaving the main canal in the inferior and posterior portion of the pterotic, the operculo-mandibular branch passes into a small tube of bone which traverses the region between the pterotic and preoperculum, along the superior and posterior borders of the hyomandibular bone. Parker and Bettany regard this small tube-like bone as a supra-temporal. It cannot, I think, be regarded as other than one of the drainpipe-like canal-bones which conduct the main canal and branches over the greater part of the skull, and homologous with those figured and described in *Amiurus catus* (see p. 280). Entering the apex of the preoperculum, the canal traverses the anterior border, passing through the whole length of the bone. In its course it gives off fine branches, which are distributed over the inferior border of the bone; a number of finer branches pass off over the superior portion of the preoperculum. Leaving the preoperculum, a small dermal connection conducts the branch into the articular portion of the mandible, entering it on its lateral border. It passes downwards and forwards and into the dentary, traversing the ventral portion of the same. In the anterior portion of the dentary the branch divides in the substance of the bone, anastomosing previous to opening at a terminal pore. There is no connection between the two branches of either side.

3. The OCCIPITAL COMMISSURE leaves the main canal on the inner border of the pterotic, and makes an anterior flexure over the region of the supra-occipital, and meets with the main canal of the opposite side.

I have not figured or described the innervation, as the distribution of the cranial nerves is almost identical with that of *Esox lucius*.

Variation.

In the Salmon there seems to have once been a series of canals passing through certain bones of the head which have been replaced by the system borne by the series of drainpipe-like canal-bones already described.

In young examples a series of canals are easily traced in the parietal, frontal, supraethmoid (Parker), and nasal bones. These canals vary a little in different specimens, but, generally speaking,